Penn Frontotemporal Degeneration Center

Penn
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Automated Analysis of Natural Speech in Amyotrophic Lateral Sclerosis

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Background:
What do we know about speech in ALS?

- Impairments in
  - grammatical processing
  - action verb knowledge
  - discourse and social communication
  - Reading time (prolonged)

Speech is a multidimensional skill requiring the collaboration of multiple cognitive and motor domains. Our study assesses the interactions of motor and cognitive impairments on acoustic-prosodic aspects of speech in ALS and ALS-FTD.

Potential motor & cognitive effects on speech in ALS

Cognitive

- Behavioral (more common)
  - Social
  - Executive
- Linguistic
  - Agrammatism (more common)
  - Semantic
  - Audio-verbal

Motor

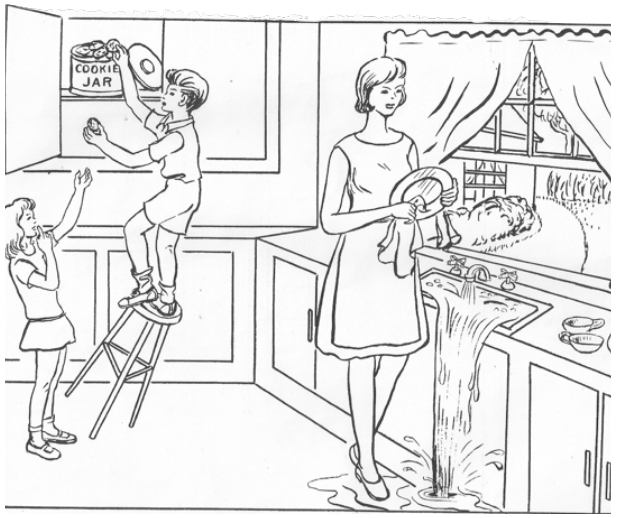
- Bulbar disease
- Reduced respiratory capacity

Study objectives

- Characterize acoustic-prosodic properties of speech in ALS spectrum
- Identify motor vs. cognitive effects on speech in ALS spectrum
- Implementation and validation of automated speech recognition in clinical settings

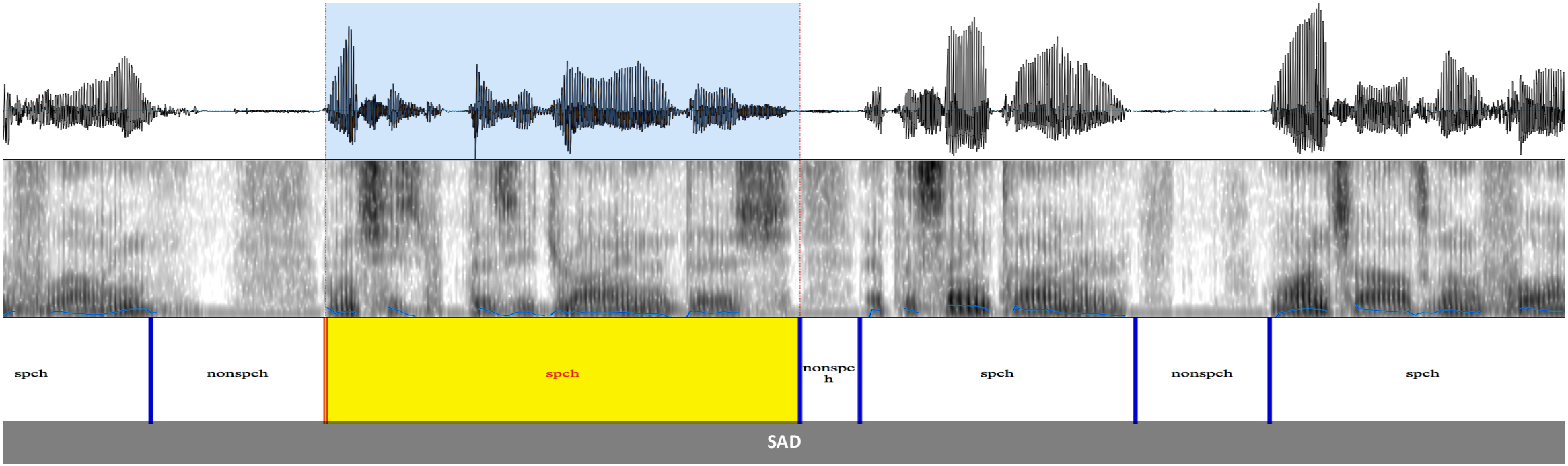
Hypothesis

- Acoustic features of speech in speakers with ALS and ALS-FTD can provide distinct markers that reflect motor and cognitive impairments.



Methods

- Digitized narrative speech samples - picture description task
- Automatic segmentation with a speech activity detector (SAD)



Methods – patient groups

Clinical & Demographic characteristics - Mean (SD)						
	ALS	ALS-FTD	HC	bvFTD	naPPA	p
n	44	23	33	90	23	
Sex = Male (%)	23 (52.3)	17 (73.9)	13 (39.4)	56 (62.2)	12 (52.2)	0.076
Age (y)	62.4 (10.4)	64.6 (8.8)	67.6 (6.2)	62.8 (8.7)	70.6 (9.2)	<0.001
Education (y, n=210)	15.1 (2.8)	13.4 (2.1)	16.1 (2.5)	15.8 (2.8)	15.2 (3.0)	0.004
Symptom duration (y, n=179)	3.7 (2.6)	4.4 (3.6)	NA	4.4 (3.2)	3.4 (1.8)	0.408
Bulbar disease = yes (%)	16 (37.2)	8 (34.8)	NA	NA	NA	NA
%FVC (n=61)	78.5 (28.1)	63.7 (23.5)	NA	NA	NA	0.042
ALSFRS-R total score (0-48, n=61)	35.0 (7.5)	34.2 (7.1)	NA	NA	NA	0.709
ECAS total score (0-136, n=53)	115.1 (5.2)	84.7 (19.1)	NA	NA	NA	<0.001

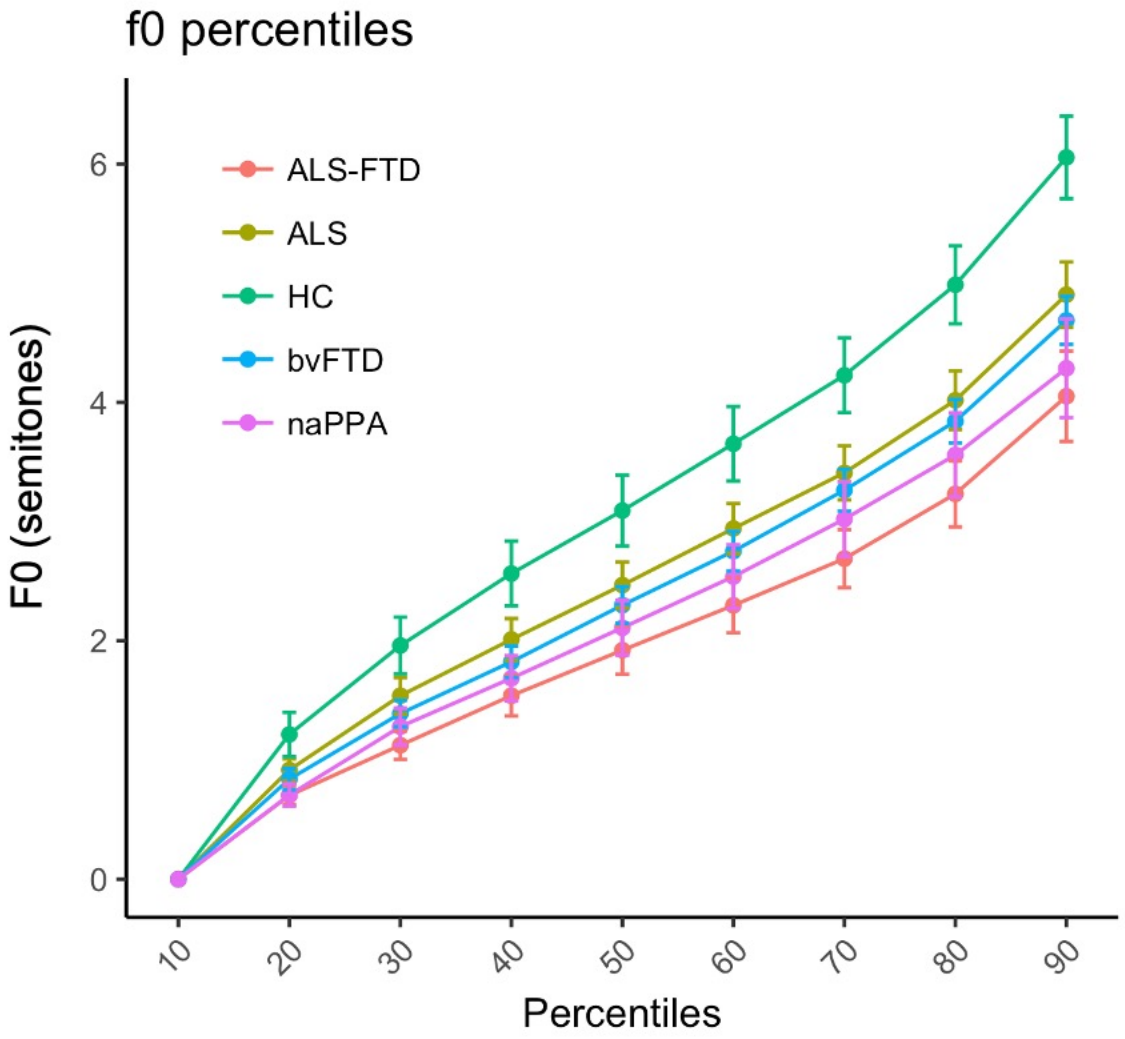
ALS - Amyotrophic lateral sclerosis; ALSFRS-R - ALS functional rating scale revised; ALS-FTD - ALS with frontotemporal dementia; bvFTD - behavioral variant FTD; ECAS - Edinburgh Cognitive Assessment Scale; %FVC - forced vital capacity (% of predicted by age); HC - healthy control; MMSE - minimental status examination; NA - not available; naPPA - nonfluent/agrammatic variant of Primary progressive aphasia; SD - standard deviation; y - years.

Methods – cont.

- Pitch tracking of continuous speech segments
- Duration measures for speech and silent pause segments
- Calculated acoustic measures: fundamental frequency (f0) range, mean speech and total speech durations, pause rate.
- Statistical analyses:
  - Group comparisons (controlling for age and education, adjusting for multiple comparisons)
  - Linear regression models:
    - acoustic measure ~ cognitive test score + motor function
    - cortical atrophy (MRI T1) ~ acoustic measure

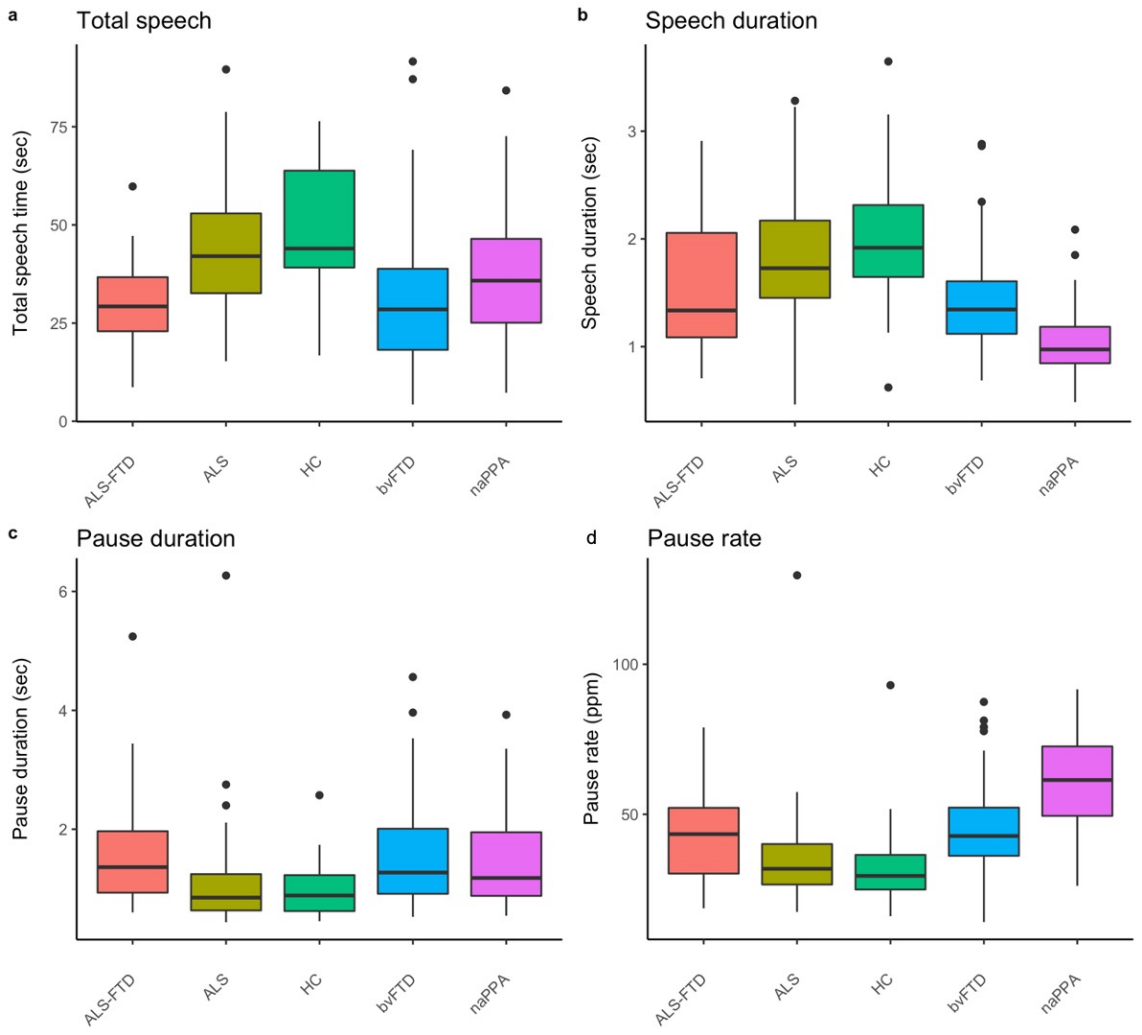
Results

- f0 range is narrow in ALS spectrum disorders compared with normal speakers



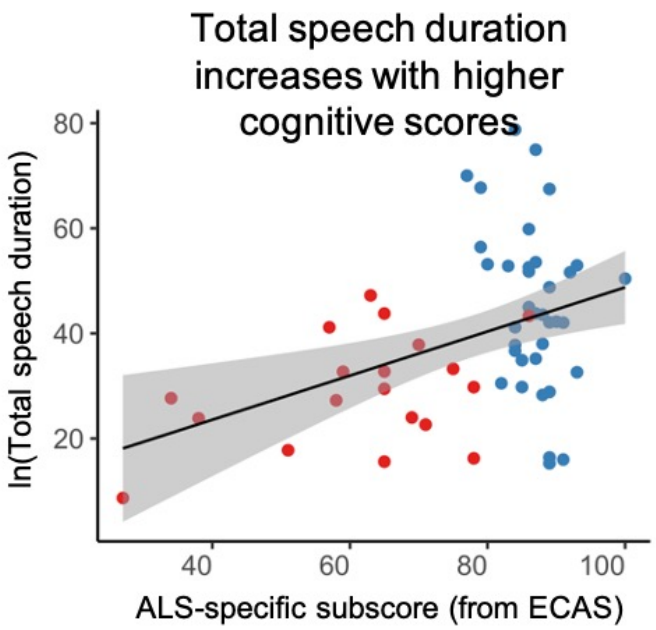
Results - cont.

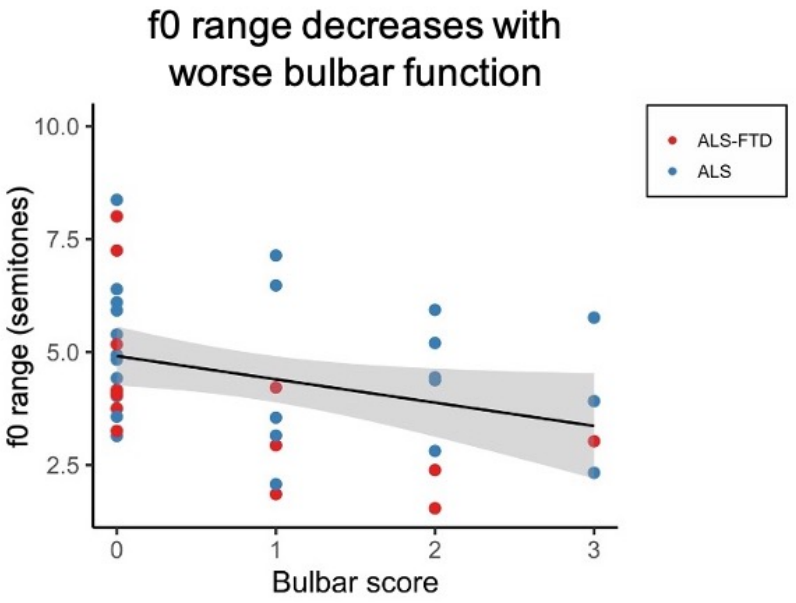
- Mean speech segment duration and total speech duration were shorter in ALS-FTD compared with normal and ALS speakers
- Pause duration and rate were impaired in ALS-FTD compared with normal and ALS speakers
- ALS-FTD speakers' durational acoustic features most resemble bvFTD speakers'



Results – Clinical correlates

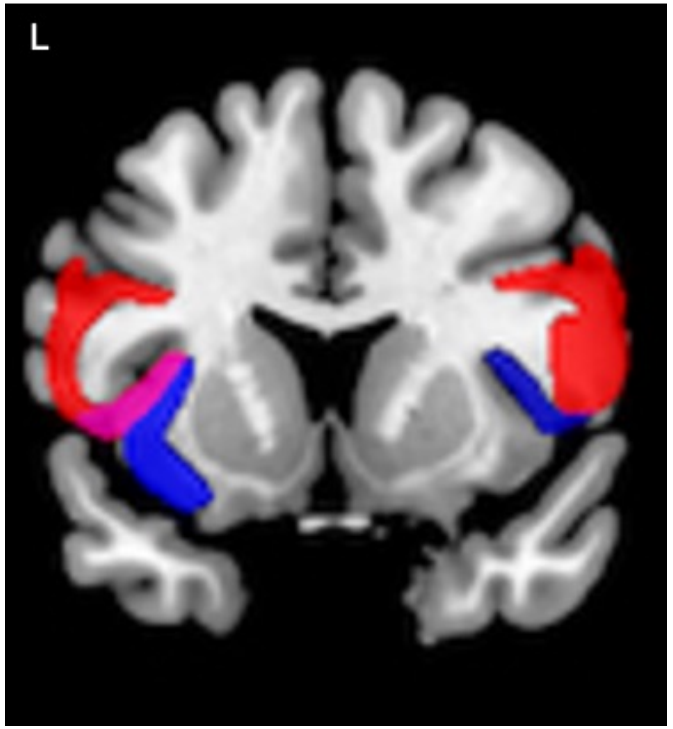
- Impaired f0 range was related to bulbar disease (beta=-0.59, p=0.012)
- Speech duration (beta=0.38, p=0.006) was related to cognitive impairment independent of respiratory function





Results – Anatomical correlates

- Impaired f0 range (red) was associated with atrophy in primary motor cortex and left peri-Sylvian regions.
- Total speech duration (blue) was associated with atrophy in the IFG bilaterally.
- Lt. frontal operculum (magenta) linked to both f0 and speech



Conclusions

- Speech samples in ALS spectrum disorders can provide highly objective and reproducible markers of disease derived purely from the acoustic signal.
- Acoustic markers relate to prosodic elements of natural language such as fluency and intonation and reflect specific motor and cognitive impairments in ALS.

Resources

A full-length manuscript of this study was accepted for publication in Neurology.

Please refer questions and comments to the corresponding author:

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